RESIDUUM VOLUME AND SHAPE ASSESSMENT AFTER LOWER LIMB AMPUTATION: VALIDITY AND RELIABILITY OF A NEW STRUCTURED LIGHT 3D SCANNER

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BACKGROUND

Objective assessment methods to monitor residuum volume are required after lower limb amputation to aid decision making in determining when the amputee can start wearing a prosthesis and to enable design of new prosthetic sockets that can improve fit and comfort [1]. Many techniques have been described and computer aided systems, including 3D scanners, present numerous advantages, but currently no definitive clinical method is available. The recent Artec Eva scanner (Artec, Luxembourg) based on laser free technology, can capture geometry and colour (for anatomical landmark identification) without the need for reference targets [2], and it could potentially be a more effective solution compared to the current methods used in clinical practice.

AIM

The aim of this study is to analyse variation in measurements of transtibial and transfemoral residuum model volumes and shapes, using the Artec Eva scanner, and to validate it against a high precision and resolution laser scanner (Romer - Hexagon, UK).

METHOD

In this study, ten residuum models (5 transtibial and 5 transfemoral, of both foam and plaster construction) were scanned by three operators, on three occasions each, using the Artec and Romer scanners. Three 4 mm diameter markers were placed on each model to identify anatomical points that determine a plane used as the proximal end of the scan. Each Artec scan, exported as an stl file, was manually aligned with the respective Romer scan using the anatomical references to compare the two volumes (Geomagic - 3D Systems, USA and Artec Studio 9.2 - Artec Group Luxembourg, Luxembourg). Validity of the Artec scan was assessed using the Bland-Altman method [3], and repeatability coefficients were calculated using one-way analysis of variance [3, 4]. In addition, root mean square error (RMSE) was calculated to observe differences in the residuum model shape.

RESULTS

Volume recorded in this analysis ranged from between 885 ml and 4400 ml. Results for the validity analysis of the Artec scanner against the Romer scanner are shown in Fig. 1 as percentage of the original volume. Mean bias was 1.4% (Confidence limits: 1.3, 1.5%), R^2 = 0.99. Coefficient of variation (CV) was 0.34%. The average RMSE value calculated in three dimensions between Artec and Romer scan ranged from 0.23 to 0.65 mm, with Artec scanner presenting slightly higher values than the Romer scanner. Intra-rater volume variability (repeatability coefficient) was 13.94 and 5.90 ml for the Artec and the Romer scanners respectively. Inter-rater variability (reproducibility coefficient) was 18.55 ml and 6.39 ml for the Artec and the Romer scanners respectively. Interclass correlation coefficient was 0.99 for both the coefficients.

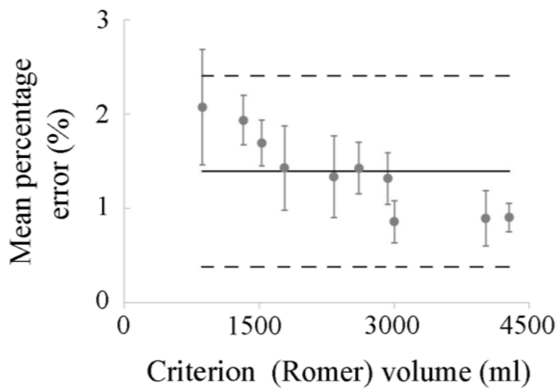

Figure 1. Modified Bland-Altman plots displaying the error of the volume (bias) measured with the practical (Artec Eva) scanner expressed as a percentage of the Romer scanner original volume (average between trials). The dashed lines indicate the upper and lower 95% limits of agreements.

DISCUSSION & CONCLUSION

The use of the Artec scanner showed a high degree of accuracy (<2%) in volume measurements and a very small magnitude for RMSE. Artec maximum average RMSE was 0.69 mm, with the highest differences highlighted at any severe prominences of the models. Repeatability coefficients for the Artec scanner increased when different operators performed the scans. However these coefficients were were 55% (for inter-rater coefficient) and 66% (for intra-rater coefficient) lower compared to the ones reported for the Omega Tracer scanner (42 ml), considered as the most reliable scanner for residual limb volume monitoring in clinical practice [4]. In conclusion, the Artec scanner has been shown to be a promising alternative for objective assessment of the residuum volume and shape change in lower limb amputees. This process will be repeated in vivo on amputees to collect information for prosthetic design purposes.

REFERENCES

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